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A comparative study of nanofluid (Al_2O_3) and distilled water in terms of thermal conductivity

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Abstract
The transfer of heat energy between fluids is frequently used in various processes in industries. The subject of potential heat energy enhancement is great attention in research. With increase in thermal conductivity of fluid, the efficiency of heat transfer in machines can be improved.
In this research work, a comparative study is carried out to investigate the effect of Al_2O_3 Nanofluid on the thermal conductivity with distilled water. KD2 pro thermal property analyzer is used in this work to measure the thermal conductivity. The Al_2O_3 nanoparticles of the nanofluid have been characterized by using Scanning Electron Microscope, Transmission Electron Microscope, UV-VIS-NIR. Experimentally, it is found that maximum enhancement in thermal conductivity was 8.7% at 80 °C of 0.1 wt % concentration.

Keywords: Nanofluid introduction, thermal conductivity, SEM, TEM, UV-VIS-NIR

1. Introduction
There are so many industrial processes which involve the transfer of heat energy. In any industrial process heat must be added or removed. It can also be transfer from one to another stream. Heat become plays a major role to fulfill the necessity of industries. In past decades, solid micro sized particles even millimeter sized particles were used with base fluid. These large sized particles created many problems in industries and troublesome in machines such as corrosion, deposition of debris in fluid flowing pipes which reduces the efficiency of machines. By using nanofluids these problems could be sort out and efficiency of heat transfer can be improved. Nanofluids having high dispersion stability, better lubrication, ability to ultrafast heat transfer, reduce friction coefficient, high specific surface area. (Uher *et al*. 2004). Nano-fluid may be defined as a fluid which containing nano sized particles or nano particles. In nanofluids there is colloidal suspension of nano particles in base fluid. If we add nanoparticles of metal in the fluids then it is called metallic Nano fluids. It has been reported that maximum enhancement in thermal conductivity of heat transfer of fluids have been observed when less amount of metallic and other particles were dissolved in these fluids. Thermal conductivities of nanofluids which contain solid particles are mainly greater than predicted values by theories of different materials. There are many research groups which are experimentally studied and reported the thermo physical properties of CNT suspensions are more than those of other nanoparticles which have the same volume fraction [1-3]. Choi [4] who proposed first time nanofluids found that the thermal conductivity of coolant increased by addition of nanoparticles in base fluids and it could improve the heat transfer performance of the coolant. After that a new name nanofluids came into existence in this field. The Thermal conductivity of fluids is low. Nanofluids can improve the thermal conductivity of fluids. There is following some mechanism by which enhancement in the thermal conductivity in nanofluid can be predicted.

1.1 Mechanism behind the enhancement of thermal conductivity of Nanofluids
1.1.1 Brownian motion
It is the random movement of particles suspended in the fluid and gases resulting from their collision or dispersion with fast-moving nanoparticles /molecules in the fluid. Parasher *et al*. (2005); Jang *et al*. (2004); and Koo *et al*. (2005) suggested Brownian motion plays a major role to control the thermal conductivity of nanofluids at micro level.

With an increase in temperature the thermal conductivity and particles motions also increases. Brownian motion produces slow motion of the nanoparticles when heat transfer takes place from one place to another. So, in the heat transfer it cannot be supposed utmost factor.

1.1.2 Thermophoresis

Thermophoresis is a phenomenon in which molecules of hot region counted high energy compare to cold region (Yu *et al*. 2003).Film boiling of nanofluids effects the enhancement in heat transfer compared to a vertical cylinder (Malvandi *et al*. 2016).

1.1.3 Nano-layer/Liquid layer

Nano layers can be formed at different interfaces between the homogeneous and heterogeneous layers of solid, liquid and gases that depend on the different processes. It plays a vital role in the field of nanotechnology. For instance, 2D Nano additives are most common in the field of food packing industries. Enhancement of thermal conductivity of 10nm particle size was shown by Yu *et al*. (2004). They found that this enhancement was due to nano/liquid layer.

1.1.4 Clustering

Clustering also affects the thermal conductivity. It is a basically a grouping of objects on the basis dissimilarity and similarity between the objects. When high concentration nanofluids are placed for a long time, clustered form of nanofluid observed. Now, due to this clustering the effective area of the thermal interaction of particles is reduced and caused decreasing in the thermal conductivity of the fluid. The difference between models developed to account for nano particle clustering and models which reflect the spatial arrangement of particles is that the nano particle clustering models include particle size dependence. The smaller particle size creates greater attraction between the individual particles, which leads to a greater extent of aggregation. To determine the thermal conductivity of an aggregate model, this includes the backbone of nanoparticles, the dead end nanoparticles and the fluid surrounding the particles.

In this article, firstly, nanofluid preparation methods are discussed briefly. It also describes the preparation technique of nano fluid with 0.1 wt% of Al_2O_3. Different characterization techniques are deliberated. It also shows that thermal conductivity of Al_2O_3 nanofluid with distilled water as base fluid is better than water. Correlation is also developed and compared with well-defined correlations.

2. Literature review

This section describes the review on enhancement in thermo physical properties and thermo hydraullic performance of nanofluid $Al_2O_3$and other nanofluids using different concentration at different temperature and different flow rate by different researchers.

Masuda *et al*. [5] experimentally studied the enhancement in heat transfer using Al_2O_3/water based nanofluid which had particle size and volume concentration are 13 nm and 1.30-4.30% respectively. They used two-step method for it and found that heat enhancement was 1.109-1.324 ratio. Akbaridoust *et al*. [6] investigated the difference between dispersion and experimental model of different helical coils using nanofluids and found that in helical coil 1, 2, 3 the coefficient value of water-CuO (0.1%) is 3.22, 3.76, 2.63 respectively and the coefficient value of water-CuO (0.2%) is 2.99, 4.27, 3.1 for same helical coils. The difference between these models was about 4% and it had been decreased. Wen *et al*. [7] experimentally studied the effects in convective heat transfer of γ-Al_2O_3nanopowder in a tube of copper by using pure water. The maximum enhancement in heat transfer enhancement was observed at inlet and after that it continuously decreased. When x/D is 63 the enhancement is 47% and when x/D is 173 it decreased to 14% at Reynolds number = 1600. Bianco *et al*. [8] numerically studied the hydrodynamic and thermal behaviour of Al_2O_3 water based nanofluid in a circular tube. By them the single-phased model isused. They find out the difference between their values which results the augmentation in heat transfer. Eastman *et al*. [9] found that the thermal conductivity of Cu EG nanofluids is increased about 40%. Liu *et al*. [10] experiment the thermal conductivity of Cu/water nanofluids. In result 23.8% improvement were found and thermal conductivity of nanofluid increases with increases in particles volume fraction & decreases with elapsed time. Lee *et al*. [11] revealed due to addition of surfactant in the nanofluid during preparation of nanofluids thermal conductivity of nanofluids is largely affected. This addition of surfactant (sodium dodecyl benzene sulfonate) in the nanofluid leads to enhancement of thermal conductivity of Cu/water (0.1%) nanofluid was 10.7%. Lee and Mudawar [12] compared the stability of nanoparticles of Al_2O_3. They found when Al_2O_3 nanofluids kept for 30 days exhibits some settlement of nanoparticles at the bottom of container compared to fresh nanofluid. This was indicated for the long time, degradation in the thermal properties of Al_2O_3nanofluids could be found. Vasu *et al*. [13] studied the effect on pressure drop in compact heat exchanger along with nanofluids (Al_2O_3) and they found the pressure drop of 4% Al_2O_3/water nano fluids was almost double that of the water. So, it is cleared from this study the pressure drop also increases by adding nanofluids in compact heat exchanger. It is also effects the thermal conductivity of nanofluid. Suresh *et al*. [14] Experimentally studied the pressure drop and convective heat transfer characteristics of Al_2O_3/Cu-water hybrid nanofluids with 0.1% volume concentration in a uniformly heated circular tube through fully developed circular tube. The experimental results shows the maximum enhancement of 13.56% in Nusselt number of nanofluids compared to Nusselt number of water at Reynolds number of 1730.The friction factor of Al_2O_3-Cu/water hybrid nanofluids at 0.1% is slightly higher than 0.1% of Al_2O_3- Cu /water based nanofluids. Chandrashekhar *et al*. [15] experimentally studied that friction factor and heat transfer characteristics of Al_2O_3/water based nanofluid of 43nm size and 0.1% vol. concentration flowing through uniformly heated circular pipe under laminar flow with wire and without coils inserts. In fully developed region the Nussult number were measured and found that there is increment of 12.24% at the Re=2275.At Reynolds number of 2275 the increment in nusslet number has been recorded by 15.91% and 21.53% after the two wire coil inserts with pitch ratio 2 and 3 respectively of Al_2O_3 nanofluid compared to distilled water. Pastoriza-Gallego *et al*. [16] experimentally studied the thermo physical properties of nanofluid. Thermal conductivity changes with both concentration (6.9 vol%) & temperature for nanoparticles in EG were measured. The results found that the enhancement in thermal conductivity 45% at T = 343.15 K and 6.9% volume fraction. Table 1 shows the enhancement in thermal conductivity as studied in above said literature,

Table 1: Thermal Conductivity Enhancements

Author	Concentration (vol. %)	Nano particle used	Nanofluid used	Method of preparation	Particle size (nm)	Enhancement (ratio)
Lee *et al.* [17]	1.00-4.30	Al_2O_3	Distilled Water	Two-step method	38.4	1.03-1.10
Wang *et al.* [18]	3.00-5.50	Al_2O_3	Distilled Water	Two-step method	28	1.11-1.16
Xie *et al.* [19]	1.80-5.00	Al_2O_3	Distilled Water	Two-step method	60.4	1.07-1.21
Das *et al.* [20]	1.00-4.00	Al_2O_3	Distilled Water	Two-step method	34.8	1.02-1.09
Chon *et al.* [21]	1.00	Al_2O_3	Distilled Water	Two-step method	11	1.09
M.J. Pastoriza-Gallego *et al.* [23]	1%	ZnO	Ethylene Glycol	Two-step method	30-60	45% at T = 343.15 K and 6.9% volume fraction
M. Chandra Sekhara Reddy *et al.* [24]	0.2% to 1.0%	TiO2	ethylene glycol–water	Two-step method	21	10.64% and 14.2% respectively.
Madhusree Kole, T.K. Dey [25]	0.016	ZnO	surfactant free and stable ethylene glycol (EG)	Two-step method	<50	~22%.
Wei Yu, *et al.* [26]	5.0%	ZnO-EG	Ethylene Glycol	Two-step method	10–20	26.5%,
L. Godson *et al.* [27]	0.04%	Silver	Water	Two-step method	54 nm	12.4%
Arun Kumar Tiwari *et al.* [28]	0.75 vol. %.	CeO_2	distilled water	Two-step method	30 nm	39%

3. Nanofluid preparation method

There are two different techniques to preparation the nanofluids.

3.1 Single Step Preparation Methods

In this process two nanoparticles are mixed with the synthesis of the nanofluids. In this we take two reactants and combine them physically as shown in Fig.1.

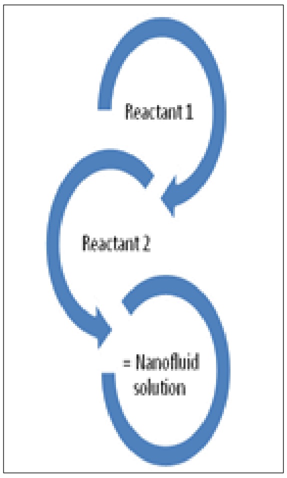

Fig 1: A Schematic View of One Step Method.

3.2 Two Step Preparation Method

It is another type of preparation of nanofluid [37]. In this existing nanopowder are mixed with base fluids by using various methods which are mechanical or chemical methods such as stirring, utrasonication etc. The two step method as shown in Fig.2.

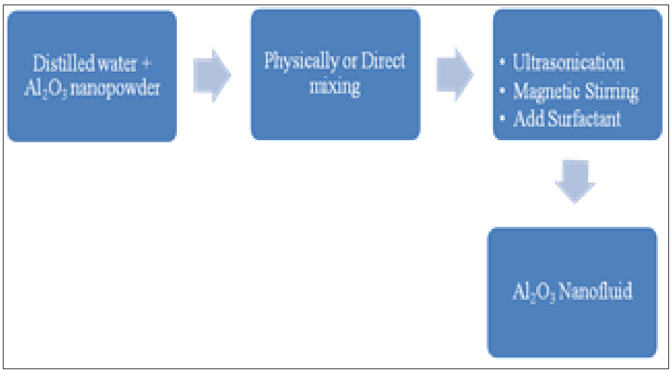

Fig 2: A Schematic Two-Step Preparation Method.

Nanoparticles of Aluminum Oxide (Average size < 80 nm) are used during the preparation of nanofluid along with distilled water as a base fluid. Table 1 Physically belongings of Aluminum oxide (Al_2O_3) nanoparticles.

3.3 Physically Belongings of Al_2O_3 Nano powder

Table 2: The table shows the physical belongings of Al_2O_3 Nano powder

Molecular Formula	Al_2O_3
Mean Particles size	< 80 nm
Al_2O_3 content	99%
Specific surface area	15 – 20 m^2/g

3.4 Flow chart Nanofluid Preparation Methods

As shown in Fig.3. Step by step preparation of nanofluid and after the preparation, the thermal conductivity of fluid will be measured.

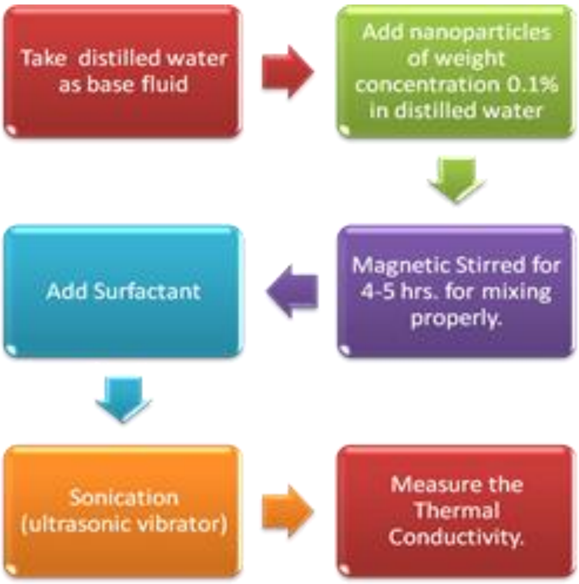

Fig 3: Flow chart complete process of experimental work.

From the above flow chart as shown in Fig. 3. it is clear that in upcoming study of the preparation and synthesizes of Al_2O_3 nanofluid would not to be too complicated. It would be easy to measure the thermal conductivity of nanofluid. The ultra sonication and magnetic stirring processes would be also easily performed.

Nanopowder of Al_2O_3 was purchased from High Purity Chemicals Private Limited (HPCL), Mumbai. Characterization such as SEM (Scanning electron microscope), TEM (Transmission electron microscope) images of the nanoparticles were performed at NIPER, Mohali (Chandigarh).Nanofluids are prepared by addition of Al_2O_3 nanoparticles at the certain concentrations into base fluid. Two step methods were performed for the synthesis of Al_2O_3 nanoparticles with distilled water as base fluids. The weight concentration of Al_2O_3 nanoparticles was 0.1% (Fig. 4). Cetyl tri ethyl ammonium bromide was used as a surfactant to more dispersion of nanoparticles in water. For mixing the nanoparticles properly in distilled water ultra sonication process was performed at department of bio &nano technology, GJU S&T Hisar. After the sonication, the magnetic stirring for 4-5 hours was also performed. At last, for experimental work the KD2 pro thermal analyzer was used to measure the thermal conductivity of Al_2O_3 nanofluids.

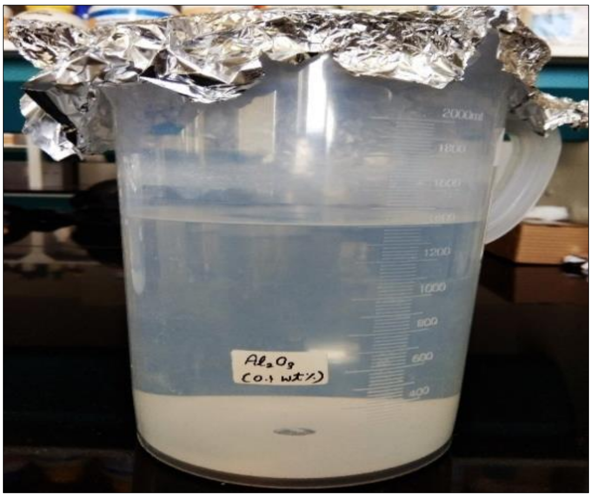

Fig 4(a): before the ultrasonication and magnetic stirring.

Fig 4(b): After the ultrasonication and magnetic stirring.

4. Characterization Techniques

There are different form of characterization techniques of Al_2O_3 nanoparticles are discussed below.

4.1 SEM (Scanning Electron Micrograph)

SEM is a technique that produces an image of sample by focuusing the beam of electrons on the surface of it. The scanning elctron micrograph (SEM) of Al_2O_3(0.1wt.%) nanoparticles shows the pesence of dumble shape of particles. The particles size distribution of Al_2O_3 nanoparticles shows the average size is 100nm (Fig.5). To break and facilate dispersion in distilled water utrasonication was done.

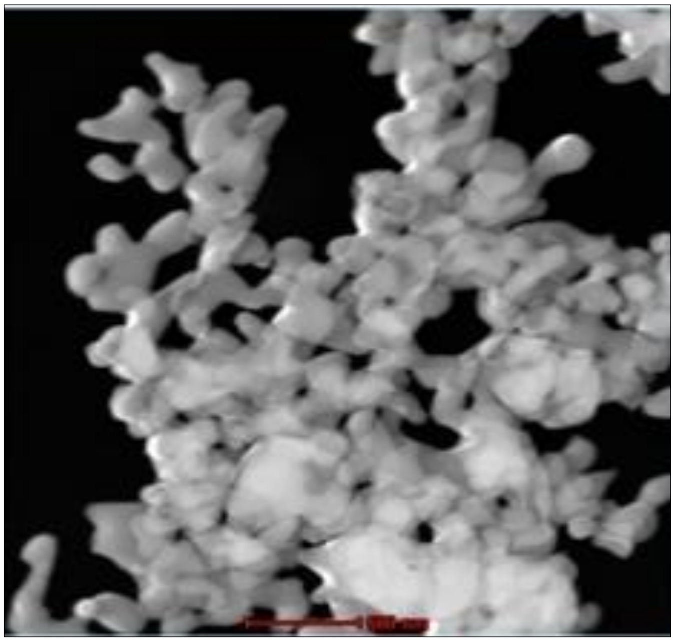

Fig 5: SEM images of Al_2O_3 nanofluid.

4.2 TEM (Transmission Electron Microscopy)

This is a technique in which a beam of electrons passes/ transmitted through the sample to forming an image of nanoparticles. Al_2O_3 water based nanofluid is used in work are dumble shaped (Fig.6).

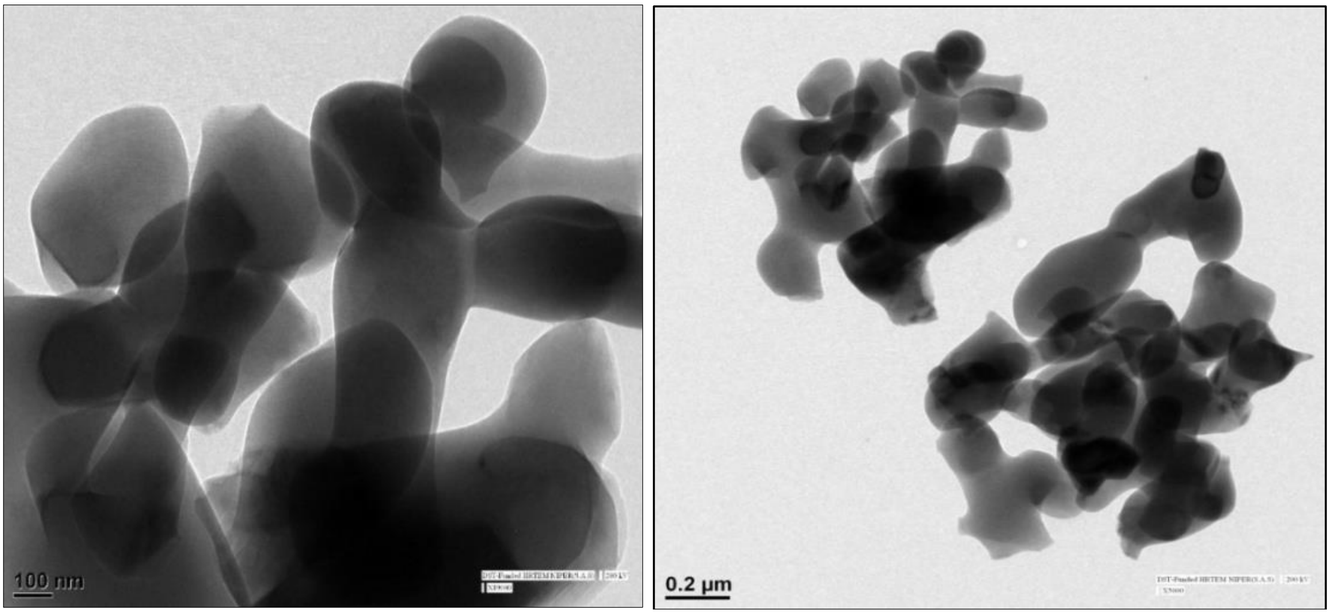

Fig 6: TEM (Transmission Electron Microscopy) image of Al_2O_3 nanoparticles

4.3 UV-VIS-NIR

This device is used to measure the absorption of light of chemical substance. Process of this spectroscopy is done by measuring the difference amount of light passes through the sample and base fluid. Fig. 7 Shows the UV image of Al_2O_3 nanofluids (0.1 wt%) which describes the highest of Abs were recorded 3 at the wavelength of 300 approximately.

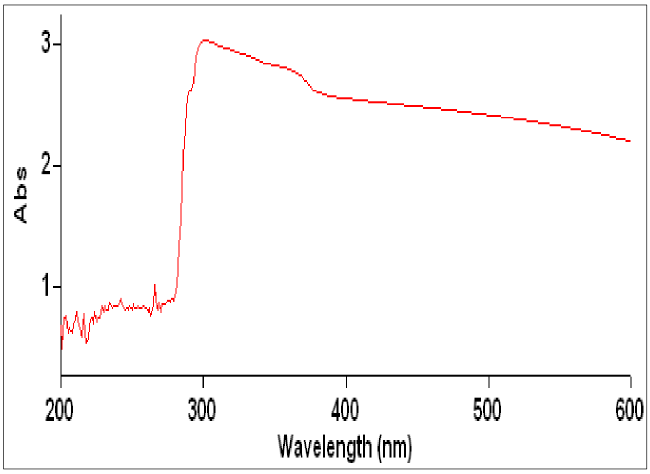

Fig 7: Image of Al_2O_3 nanofluid (0.1 Wt. %).

5. Results and discussion

5.1 Measurement of Thermal Conductivity

The KD2 pro was used for measuring the thermal conductivity 0.1% weight concentrations of Al_2O_3 nanofluids and distilled water. KD2 is decagon devices and battery-operated which is very used for measuring the thermal properties of nanofluid. It is a handled device. KD2 has a sensors kit in which three different sensors (KS1, SH1, and TS1) applicable for measuring the thermal conductivity of various liquids and solids. Thermal conductivity and resistivity of nanofluid is measured by single needle sensors. While Dual-needles sensors measures the volumetric specific heat capacity and diffusivity. Because nanofluids possess low viscosity, So KS-1 type is used for measuring as it is best suited for the liquid samples. The different Values of thermal conductivity were obtained at different temperatures. Following are the specifications of KD2 pro thermal property analyzer. Dip the sensor in the bottle and switch on the KD 2 pro. Readings at different temperatures will be recorded. Thermal conductivity of Distilled water and Al_2O_3 nanofluid (0.1 wt%) has been measured by KD2 pro at different temperatures 30°C, 40°C, 50°C, 60°C, 70°C and 80°C.

5.2 Comparison of thermal conductivity of distilled water and preparedAl$_2$O$_3$ nanofluid.

Enhacement in thermal conductivity of nanofluid (%), $k_{eff.}$ =

$$k_{eff.} = \frac{k_{nanofluid} - k_{distilledwater}}{k_{distilledwater}} \times 100$$

Where

$k_{nanofluid}$ = Thermal conductivity of Nano fluid.

$k_{distilledwater}$ = Thermal conductivity of Distilled water.

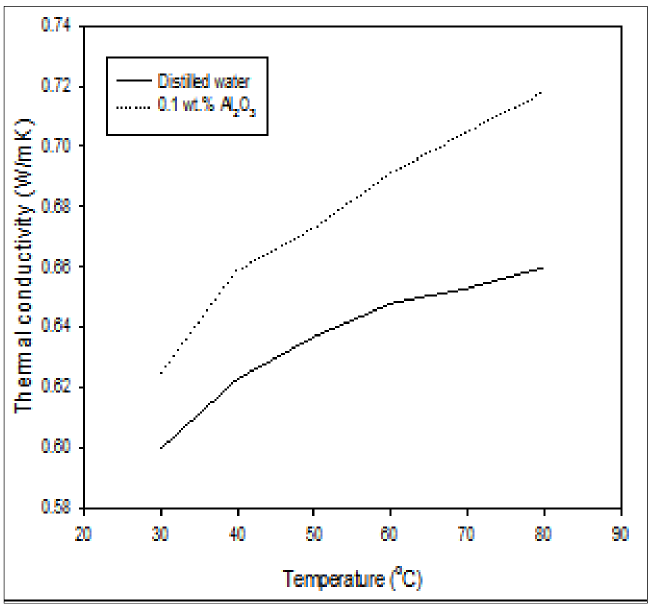

Fig 8: Comparison of thermal conductivity and distilled water at different temperature

Fig.8 shows the enhancement in thermal conductivity is much higher than enhancement in distilled water with increasing temperature. As the temperature increase, thermal conductivity of fluids increases due to rapid Brownian motion at higher temperatures. Maximum enhancement is observed at 80 ^{o}C.

5.3 Developed correlation

After measuring the thermal conductivity values, a correlation is developed using linear regression analysis. Fig. 9 shows the comparison of experimental values with theoretical values predicted from developed correlation. A quite similar trend is obtained in both values. The maximum and minimum deviation of predicted and experimental values is well within +1.39296 and -0.008085 respectively.

$$K_{corr.} = 0.4132T^{0.12573}$$

Where,
T =Temperature (varies from 30-80 ^{0}C).

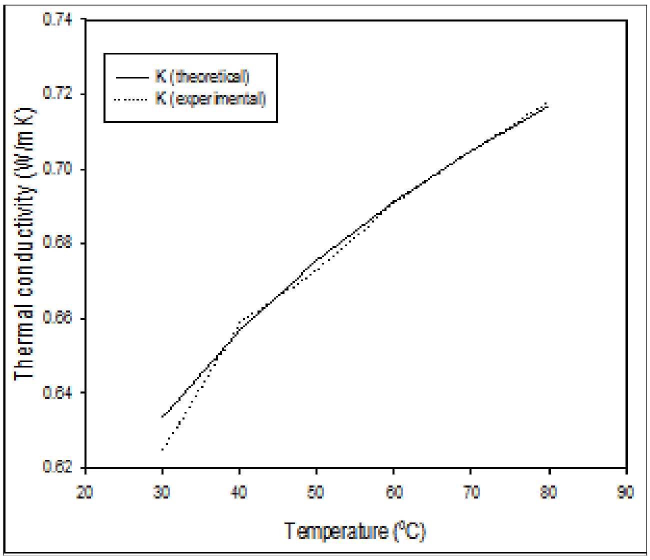

Fig 9: Comparison of theoretical and experimental thermal conductivities

6. Conclusions

In this study the enhancement in thermal conducty has been tested of Al_2O_3 Nanofluid. Nanofluid had been prepared by using Al_2O_3 nanoparticles and distilled water as base fluid. Weight concentration of 0.1% have been prepared by using Two-step Method. The Characterizaton of Al_2O_3/Distilled water Nanofluid have been also prepared by using SEM, TEM, UV-VIS-NIR. Enhancement in thermal conductivity of Al_2O_3(0.1 wt%) found 4.1%, 5.7%, 6.2%, 6.6%, 7.9%, 8.7% while compared to thermal conductivity of distilled water at 30°C, 40°C, 50°C, 60°C, 70°C, 80°C respectively. So, maximum enhancement in thermal conductivity of nanofluid experimentally found 8.7% at 80°C of 0.1 wt%.

Apart from the enhancement in thermal conductivity of Al_2O_3 nanofluid, the following conclusion can be drawn:

- SEM, TEM images shows dumble shaped particles.
- UV-VIS-NIR has recorded Abs from 0.4 to 3 relative to wavelength of range 200-600 nm.
- It is also found that with the increment of temperature the thermal conductivity of both distilled water and Al_2O_3 nanofluid also increases.
- A correlation for thermal conductivity is developed from measured values.

7. References

1. Maré T, Halelfadl S, Sow O, Estellé P, Duret S, Bazantay F. Comparison of the thermal performances of two nanofluids at low temperature in a plate heat exchanger, Exp. Therm. Fluid Sci. 2011; 35(8):1535-1543.
2. Liu MS, Lin MC, Huang IT, Wang CC. Enhancement of thermal conductivity with carbon nanotube for nanofluids, Int. Commun. Heat Mass Transfer. 2005; 32:1202-1210.
3. Xie H, Lee H, Youn W, Choi M. Nanofluids containing multiwalled carbon nanotubes and their enhanced thermal conductivities. J Appl. Phys. 2003; 94:4967-4971.
4. Choi SUS, Eastman JA, Li S, Yu W, Thompson LJ. Anomalously increased effective thermal conductivity of ethylene glycol-based nanofluids containing copper nano-particles, Appl. Phys. Lett. 1999; 78(6):474-480.
5. Masuda H, Ebata A, Teramae K, Hishinuma N. Alteration of Thermal Conductivity and Viscosity of Liquid by Dispersing Ultra-Fine Particles, NestuBussei. 1993; 7:227-233.
6. Farzan Akbaridoust, Raksha M, Abbas Abbassi, Saffar-Avval M. Experimental and numerical investigation of annofluid heat transfer in helically coiled tubes at constant wall temperature using dispersion model, Heat and Mass Transfer. 2013; 58:480-491.
7. Wen D, Ding Y. Experimentally investigation into convective heat transfer of nanofluids at the entrance region under laminar flow conditions. Int J Heat Mass transfer. 2004; 47(24):5181-8.
8. Bianco V, Chiacchio F, Manca O, Numerical investigation of nanofluids forced convection in circular pipes. Appl Thern Eng. 2009; 29(17):3632-42.
9. Eastman JA, Choi SUS, Li S, Yu W, Thompson LJ. Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing Cu nanoparticles. ApplPhysLett. 2001; 78(6):718-20.
10. Liu M-S, Lin MC-C, Tsai CY, Wang C-C. Enhancement of thermal conductivity with Cu for nanofluids. Using chemical reduction method. Int. J Heat Mass Transfer 2006; 49(17-18):3028-33.
11. Lee J-H, Hwang KS, Jang SP, Lee BH, Kim JH, Choi SUS *et al*. Effective viscosities and thermal conductivities of aqueous nanofluids containing low volume concentrations of Al_2O_3 nanoparticles Int J Heat Mass Transfer. 2008; 51(11-12):2651-6.
12. Lee J, Mudawar I. Assessment of the effectiveness of nanofluids for single- phase and two-phase heat transfer in micro-channels. Int J Heat Mass Transfer. 2007; 50(3-4):452-63.
13. Vasu V, Rama Krishna K, Kumar ACS. Heat transfer with nanofluids for electronic cooling. Int J Mater Prod Technol. 2009; 34(1/2):158-71.
14. Suresh S, Chandrasekar M, Sekhar SC. Experimental studies on heat transfer and friction factor characteristics of CuO/water nanofluid under turbulent flow in a helically dimpled tube. Experimental Thermal and Fluid Science. 2011; 35(3):542-549.
15. Chandrasekar M, Suresh S, Bose AC. Experimental

investigations and theoretical determination of thermal conductivity and viscosity of Al2O3/water nanofluid. Exp Therm Fluid Sci. 2010; 34:210-6.
16. Pastoriza-Gallego MJ, Lugo L, Cabaleiro D, Legido JL, Piñeiro MM. Thermophysical profile of ethylene glycol-based ZnO nanofluids. J Chem. Thermodynamics. 2014; 73:23-30.
17. Lee S, Choi SUS, Li S, Eastman JA. Measuring thermal conductivity of Fluids Containing Oxide Nanoparticles. Transactions of the ASME, Journal of Heat Transfer. 1999; 121:280-289.
18. Wang XXu, Choi SUS. Thermal Conductivity of the Nanoparticle-Fluid Mixture, Journal of Thermophysics and Heat Transfer. 1999; 13:474-480.
19. Xie H, Wang J, Xi T, Ai F. Thermal conductivity Enhancement of Suspensions Containing Nanosized Alumina Particles. Journal of applied physics. 2002; 91:4568- 4572.
20. Das SM, Putra N, Thiesen P, Roetzel W. Temperature Dependence of Thermal Conductivity Enhancement for Nanofluids, Transactions of the ASME. Journal of heat transfer. 2003; 125:567-574.
21. Chon CH, Kihm KDSP, Choi SUS. Empirical Correlation Finding the Role of Temperature and Particle Size for the Nanofluid (Al_2O_3) Thermal Conductivity Enhancement, Applied Physics Letters, paper number 153107, 2005; 3:87.
22. Li CH, Peterson GP. Experimental Investigation of Temperature and Volume fraction Variations on the Effective Thermal Conductivity of Nanofluids Suspensions (Nanofluids). Journal of Applied Physics. paper 084314, 2006; 9:98.
23. Pastoriza-Gallego MJ, Lugo L, Cabaleiro D, Legido JL, Piñeiro MM. Thermophysical profile of ethylene glycol-based ZnO nanofluids. J Chem. Thermodynamics. 2014; 73:23-30.
24. Chandra Sekhara Reddy M, Vasudeva Rao V. Experimental studies on thermal conductivity of blends of ethylene glycol-water-based TiO_2 nanofluids, International Communications in Heat and Mass Transfer. 2013; 46:31-36.
25. MadhusreeKole, Dey TK. Thermophysical and pool boiling characteristics of ZnO-ethylene glycol nanofluids, International Journal of Thermal Sciences. 2012; 62:61e70.
26. Wei Yu, HuaqingXie, Lifei Chen, Yang Li. Investigation of thermal conductivity and viscosity of ethylene glycol based ZnO nanofluid, ThermochimicaActa. 2009; 491:92-96.
27. Godsona L, Deepak K, Enoch C, Jefferson B, Raja B. Heat transfer characteristics of silver/water nanofluids in a shell and tube heat exchanger, archives of civil and mechanical engineering. 2014; 14:489-496.
28. Arun Kumar Tiwari, Pradyumna Ghosh, Jahar Sarkar. Heat transfer and pressure drop characteristics of CeO_2/water nanofluid in plate heat exchanger, Applied Thermal Engineering. 2013; 57:24e32.
29. Khdher AM, Sidik NAC, Hamzah WAW, Mamat R. An experimental determination of thermal conductivity and electrical conductivity of bio glycol based Al_2O_3 nanofluids and development of new correlation. Int Commun Heat Mass Transfer. 2016; 73:75-83.